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HIGH-ENERGY EMISSION FROM ACCRETING BLACK HOLES WITH HIGH-MASS DONOR STARS

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We present an analysis of the interactions of a distribution of relativistic protons under the typical conditions of the corona surrounding an accreting black hole. The model is applied to a concrete binary system with a high-mass donor star: the classical source Cygnus X-1.

Many galactic black holes present a very high X-ray luminosity. The mechanism underlying the emission is the accretion from a main sequence companion star. If this star is an early-type, hot star, the accretion takes place through the strong stellar wind. Part of the accreting matter is in the form of hadrons. If these particles are accelerated up to relativistic energies, very high energy radiation of hadronic origin becomes possible. Several hadronic models have been proposed to explain the γ-ray emission from X-ray binaries detected in recent years (Romero et al. 2005; Romero & Orellana 2005). The aim of this work is to show that the region immediately surrounding the black hole (the *corona*) might be a site of efficient γ-ray production. As a case of study, we adopted the characteristic parameters of Cygnus X-1 to model the corona, see Poutanen et al. (1997) for details. The corona is a hot, dense plasma of thermal electrons and ions, with a radius of $\sim$ 550 km. The coronal radiation field is a power law, $n_{\rm ph} \propto E_{\rm ph}^{-1.6}$, that extends up to $\sim$ 150 keV. Our estimates give a magnetic field strength of $B \sim 6 \times 10^6$ G. The distribution in energy of the relativistic protons also follows a power law, $n_p(E_p) \propto E_p^{-2.2}$. The value of the spectral index is consistent with acceleration by shock waves (Fermi mechanism). The balance between cooling and acceleration rates yields an upper limit of $\sim 10^{16}$eV to the energy of the relativistic protons. Under the conditions in the corona, protons cool more efficiently through synchrotron radiation and inelastic collisions with thermal protons (pp) and photons ($p\gamma$). For further details on these results and the coronal model, see Romero & Vila (2006). The production spectra related to these three processes are shown in Figure 1. Synchrotron radiation is responsible for the low-energy part of the spectrum. The most energetic photons are produced in pp collisions, reaching energies up to $\sim 10^{15}$eV. Like the parent proton distribution, the spectrum follows a power law. The contribution from $p\gamma$ interactions is completely negligible.

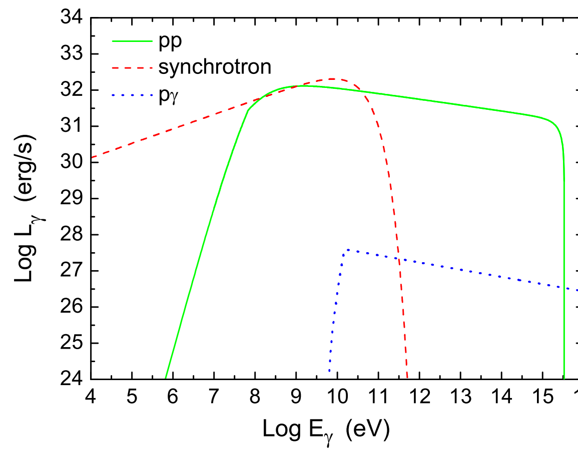

Fig. 1. Production spectra of hadronic origin. Very high-energy radiation is produced through pp collisions.

Further calculations indicate that the opacity to the propagation of the created γ-rays is very high. A wide band in the spectrum (10^7eV$\leq E_\gamma \leq 10^{12}$eV) is absorbed producing pairs through annihilation of γ-rays with the coronal X-ray field, $\gamma\gamma \rightarrow e^{\pm}$. Pairs are also injected through decay of $\pi^{\pm}$ created in pp and $p\gamma$ collisions. They cool through synchrotron radiation, emitting new photons that are absorbed, triggering an electromagnetic cascade. The cascade degrades the energy of the primary photons, until it falls below the pair creation threshold and thus they can escape freely. The final emission spectrum must be obtained using Monte Carlo techniques, and will be the subject of future work.

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